VSim 2.0 is a flexible piece of software for interacting with 3D content in educational settings. At first launch, the software appears deceptively simple (upper left image), but it facilitates sophisticated interactions with academically generated real-time models. The VSim 2.0 screenshot above shows the Street in Cairo installation on the Midway Plaisance from the Urban Simulation Team's 3D computer reconstruction of Chicago's World's Columbian Exposition of 1893, an example of a real-time model being built at UCLA and intended for educational use. The thumbnails across the top of the simulation window show a portion of a linear narrative describing the space. Embedded primary and secondary resources, websites, and annotations can be accessed from the bar along the bottom of the simulation window. The different colors refer to different categories of information (e.g., photographs, renderings, architectural drawings, and ephemera). At right are examples of two launched resources related to the Street in Cairo: an image from a private collector of the wedding procession held regularly in the Street of Cairo, and a lantern slide from Ryerson and Burnham Archives at the Art Institute of Chicago.

White Paper – December 27, 2018[1]

NEH Digital Humanities Implementation Grant #HD-50164-14

VSim: Interface software and online repository and archive to facilitate distribution and educational use of three-dimensional computer models of historic urban environments

Project Co-Principal Investigators: Lisa M. Snyder and Scott Friedman
(UCLA's Office of Information Technology/Institute for Digital Research and Education)

https://idre.ucla.edu/research/active-research/vsim
https://vsim.library.ucla.edu/xmlui/

Abstract

UCLA has a long history of 3D work, beginning in the 1980s with the Urban Simulation Team at UCLA directed by Bill Jepson, and continuing with the historic reconstruction computer models spearheaded by Bernard Frischer and Diane Favro, first working with the Urban Simulation Team, then through their own CVRLab (the Cultural Virtual Reality Lab), and finally with the Experiential Technologies Center directed solely by Favro. Both VSim PIs – Snyder and Friedman – worked with Jepson on the Urban Simulation Team, with Snyder exploring educational

---

[1] This white paper was due to the NEH on December 31, 2018. The agency, however, fell victim to the U.S. government shutdown, and the NEH's electronic grant management site was taken down when their funding expired on December 21. The document was eventually submitted on January 28, 2019, when NEH funding was restored.

applications for real-time technology, and Friedman focusing on real-time rendering and computer graphics. The following white paper describes both the intent and outcome of the NEH-funded VSim project, and the nature of scholarship that focuses on 3D materials.

VSim 1.0 (the prototype)

The VSim prototype was funded with an NEH Start-Up Grant (HD-50958-10). The goal of the grant was to develop a generalizable and extensible prototype for software that allowed real-time exploration of highly detailed, three-dimensional computer models of historic urban environments in both formal and informal educational settings. This proof-of-concept effort created the initial framework for software that gave scholars and educators mechanisms to explore, annotate, craft narratives, and build arguments within 3D space – in essence, facilitating the creation of virtual learning environments that could be broadly disseminated to educators and learners across grade levels and humanities disciplines.

The genesis and design of the VSim interface was described in the white paper generated for the original NEH grant:

> The original VSim proposal sprang out of [Lisa M. Snyder's] 2003 Ph.D. dissertation on the use of interactive computer models for the study and teaching of historic urban environments. … The design of VSim was grounded on three basic presuppositions. First, that academically generated, highly detailed interactive 3D computer models of historic urban spaces offer distinct advantages over static imagery for teaching and learning about the built environment. Second, that attempts to integrate such content into the classroom should accommodate the prevailing teaching and learning methods of disciplines focused on the built environment. And, finally, that it should be possible to re-purpose existing content for use in both formal and informal educational settings.

> This focus on classroom use dictated a number of specific design choices. With a nod to Larry Cuban and his book *Teachers and machines: the classroom use of technology since 1920*, the development team's keywords were simplicity, versatility, and efficiency.[2] We worked to package a very complex set of interactions with 3D content into a simple, non-threatening framework for integrating virtual environments into the classroom – no small feat. We stripped the graphics down to simple familiar icons that mimic operations in commonly used software packages and minimized the menus required for interaction. To encourage use, the software had to meet a very low technological threshold – our mantra was simple, simple, simple – and we added the COLLADA loader to accommodate simple projects built in low-cost or free modeling packages like Trimble's Sketch Up as well as high-end academic content built in sophisticated modeling packages like Autodesk's 3ds Max. Our goal was a versatile framework that catered to discovery learning, but was flexible enough to be used for teacher-centered presentations (i.e., lectures), student-centered activities (i.e., assignments), and a wide array of learning objectives. The power of this versatility is directly proportional to its efficiency: content creators, educators, or users can elect to use the navigation,

---

[2] Larry Cuban's conclusion about instructional technology is that it often fails to gain acceptance because "the simplicity, versatility, and efficiency of … aids such as the textbook and chalkboard in coping with problems arising from the complicated realities of classroom instruction far exceed the limited benefits extracted from using machines." Larry Cuban, *Teachers and machines: the classroom use of technology since 1920*, (New York, Teachers College Press, 1986) 59.

narrative, and embedded resource features in innovative combinations to support the construction of knowledge as is appropriate for their content.[3]

The prototype software (VSim 1.0) was released in June 2013 in both Windows- and Mac-compatible versions. Additional features were eventually added to the Windows version of the software (creating version 1.2.1). The software, a sample model of the Pantheon created by UCLA's Experiential Technologies Center, user guides, and links to tutorials and presentations that feature the software were made available online.

VSim 2.0 (the production-level version of the software)

In 2014, PIs Snyder and Friedman received an NEH Digital Humanities Implementation Grant to (1) develop a production-level version of VSim, a generalizable and extensible software interface that allows real-time exploration of highly detailed, three-dimensional computer models in both formal and informal educational settings, and facilitates peer review and educational use of 3D content; and (2) create, in partnership with the UCLA Digital Library Program, an online project repository and archive for the dissemination of 3D content across grade levels and humanities disciplines.

The newly released VSim 2.0 includes the same three main components of the prototype, but with significant enhancements. The software allows **three modes of navigation** (WASD gamer-style interaction, flight simulation, and object rotation). It includes a **narrative feature** that allows content creators, educators, or general users to create, play, and share linear presentations. These narratives are akin to PowerPoint presentations, but in 3D space where the individual nodes (the VSim equivalent of slides) can be overlaid with text and imagery. Finally, the software includes an **embedded resources feature** that allows the content creator or user to annotate the 3D space with spatially aware text or links to primary or secondary resources online or on the host computer. Embedded resources provide users access to annotations, multi-media files, and websites related to the modeled environment. (These features can be seen in the illustration on the first page.)

The deliverables of the grant – VSim 2.0 and the online VSim Repository and Archive – are now largely completed and available online at *vsim.library.ucla.edu*. Lead programmer David Stephan successfully completed the production-level beta code for VSim 2.0, and released both Windows and Mac versions on December 12, 2018. Links to the beta releases were posted on December 19 to both the Institute for Digital Research and Education's VSim webpage and the VSim Repository and Archive. The beta versions of the software – and the final version to follow – launch with a default model of the VSim logo, an introductory narrative about the interface, and two embedded resources to suggest to users the possibilities of the interface. Library Academic Projects Developer Peter Broadwell and Programmer/Analyst Hardy Pottinger pushed the repository and archive into production in December 2017 to coincide with a publication about Digital Karnak in the *Journal of the Society of Architectural Historians*,[4] and in the months surrounding the conclusion of the grant period, they returned to the project to address some final bugs in the website.

---

[3] Lisa M. Snyder, 2013, "Software interface for real-time exploration and educational use of three-dimensional computer models of historic urban environments (VSim)," *National Endowment for the Humanities*, September 16, https://securegrants.neh.gov/publicquery/main.aspx?f=1&gn=HD-50958-10.

[4] Elaine A. Sullivan and Lisa M. Snyder, "Digital Karnak: An Experiment in Publication and Peer Review of Interactive, Three-Dimensional Content," Journal of the Society of Architectural Historians 76, no. 4 (December 27, 2017): 464-82 doi:10.1525/jsah.2017.76.4.464, http://jsah.ucpress.edu/content/76/4/464.

Work on the VSim project will continue in the months and years following the implementation grant. Some of these tasks will be completed in the early months of 2019 and can be categorized as post-grant clean-up. There are, however, longer term items that will continue so long as the software is viable and the VSim Repository and Archive remains active.

Reflections on the process (part summative evaluation, part formative)

The following discussion considers the lessons learned during the fulfillment of the now-completed NEH grants to develop the VSim prototype, VSim 2.0, and the VSim Repository and Archive. The section begins with discussions about the development process, followed by thoughts on the general viability of 3D scholarship, and concluding with consideration of the educational applications for the interactive computer reconstruction models.

THE DEVELOPMENT PROCESS

Most importantly, you need a skilled and motivated team.

The greatest challenge in fulfilling both the start-up and implementation grants was finding and securing time from the highly skilled programmers needed to build the software and the repository and archive. Both grants relied on student workers, and future work on the project will likely take a different approach. With the prototype, fulfillment dragged while the student programmers enjoyed more lucrative or career-building opportunities (e.g., TAships that came with fees, summer internships). As such, their work on the project had to occur around the edges of their busy schedules. With the VSim 2.0 interface, the challenge was finding programmers with the right skills and aptitude for the task at hand. In all, six student programmers where hired. Of those, only two were able to make significant contributions to the project, and the vast majority of the final code was the result of the effort of only one programmer – David Stephan. In hindsight, some form of a skills assessment test should have been given with the early hires to minimize the time lost as they attempted to get up to speed on the prototype code and the development environment. Short of that, those early hires should have been supervised more aggressively from the start, and let go as soon as it was apparent that they were not going to be able to contribute to the project.

Working with the three student hires involved in the software testing and content development was a very different experience as their tasks were more concrete, perhaps more traditional, and better aligned with their academic interests. As such, all three were able to make significant contributions to the project. Joy Guey worked tirelessly with authors Elaine A. Sullivan and VSim PI Snyder on the Digital Karnak Publication Prototype using VSim 1.2.1. Echo Theohar used her graphic design skills to design the templates for the VSim Repository and Archive and color palettes for introductory narratives for the first wave of models to be released. And finally, Francesca Albrezzi, a Ph.D. student in UCLA's World Arts and Cultures/Dance program, took on many tasks, and the project was all the richer for her involvement. She worked with the Library programmers on the repository and archive, tracked and managed their progress, batch uploaded materials into the repository, wrote guides and documentation, tested software, and prepped content for inclusion in the repository.

Be mindful of unexpected pitfalls.

In terms of overall management, the phrase that comes to mind as most apt for the VSim project is 'the best-laid plans of mice and men often go awry.' Not disastrously so, but the project would have progressed more smoothly had some administrative changes not occurred.

Over the arc of VSim development, both PIs took on increasingly more complex roles within their home department (UCLA's Office of Information Technology/Institute for Digital Research and Education), thereby limiting the amount of time they had available to focus on the project. Snyder was promoted to Director of Campus Research Initiatives in 2016, asked to lead an effort to make recommendations to better support research data at the campus level in 2017, and appointed in 2018 as Acting Director of the Research Technology Group, the unit at UCLA that provides campus-wide research support services and runs the shared advanced computing research cluster. Friedman applied for and received a 2015 National Science Foundation campus cyberinfrastructure grant that funded new core switch infrastructure to connect the UCLA Research Data Center Network to the UCLA Science DMZ via redundant 100Gb links. (The UCLA Science DMZ then connects to the UCLA campus backbone network, commodity internet, and research networks like Internet2 and ESnet.)

Similarly, leadership of the UCLA Digital Library Program (DLP) changed, along with the way the unit handles the management and delivery of digital content. When the implementation grant was first written, Steven Davison was head of the unit, and they were committed to developing projects using Islandora with a Drupal/Fedora/Solr infrastructure stack. By the time fulfillment was underway in 2016, Elizabeth (Lisa) McAulay had been appointed first as Acting Head, and then Head of the unit, and the DLP was re-thinking their technical approach and exploring new options for the Library's digital collections. Thus, the building of the VSim Repository and Archive was awkwardly timed at a moment of great transition. Although completely committed to the project, the early Library development effort happened in fits and starts. Initially, the site was to be developed in-house, then through a local contractor, and then an outside vendor. Ultimately, it was built in-house on DSpace by Hardy Pottinger and Peter Broadwell. At the time of this writing, however, the DLP is developing a new repository solution based on Samvera, and there may come a time when the VSim content will need to be migrated from DSpace.

THE GENERAL VIABILITY OF 3D SCHOLARSHIP

Interest in 3D work continues to grow.

In the years during the fulfillment of the VSim Digital Humanities Implementation grant, there has been a considerable amount of focused effort on 3D material. Beyond one-off modeling projects – although those do continue apace – the 3D community has matured, and begun considering 3D scholarship in the same vein as more traditional academic pursuits. This maturation is evidenced by the sheer number of grants and groups working to identify strategies to disseminate, publish, and preserve 3D materials. In this realm, the VSim project has been part of the conversation in meetings on:

- **Scholarship in 3D: A Proposal for a Digital Edition Publishing Cooperative** (funded by the National Historical Publications and Records Commission (NHPRC) and the Andrew W. Mellon Foundation; PI: Elaine A. Sullivan (UCSC)),

- **Community Standards for 3D Data Preservation** (funded by the Institute for Museum and Library Services (IMLS); PIs: Jennifer Moore (WashU), Adam Rountrey (UMich), and Hannah Scates Kettler (UIowa)),

- **Building for Tomorrow: Collaborative Development of Sustainable Infrastructure for Architectural and Design Documentation** (also funded by IMLS; PI: Ann Whiteside (Harvard)), and

- The burgeoning International Image Interoperability Framework (IIIF) 3D community group that is working to develop both open standards for 3D material and a universal viewer that can display 3D files.

There is a significant difference between sources-based and reality-based models.

Interest in 3D scholarship noted above is, however, divided into two distinct camps, one side focused on generation of 3D content based on input from real-world objects, and the other focused on the reconstruction/recreation of historic environments or events. In his 2018 article on the "The Production of 3D Digital Archives and the Methodologies for Digitally Supporting Research in Architecture and Urban Cultural Heritage," author Fabrizio Apollonio includes a graphic that nicely summarizes the difference between sources-based and reality-based models.[5] In essence, the graphic (see below), illustrates how a sources-based model is constructed from a multitude of gathered data to generate knowledge. A reality-based model, on the other hand, is generated from scans or photos of an extant object or site, and the knowledge production is as a result of the analysis of that dataset.[6]
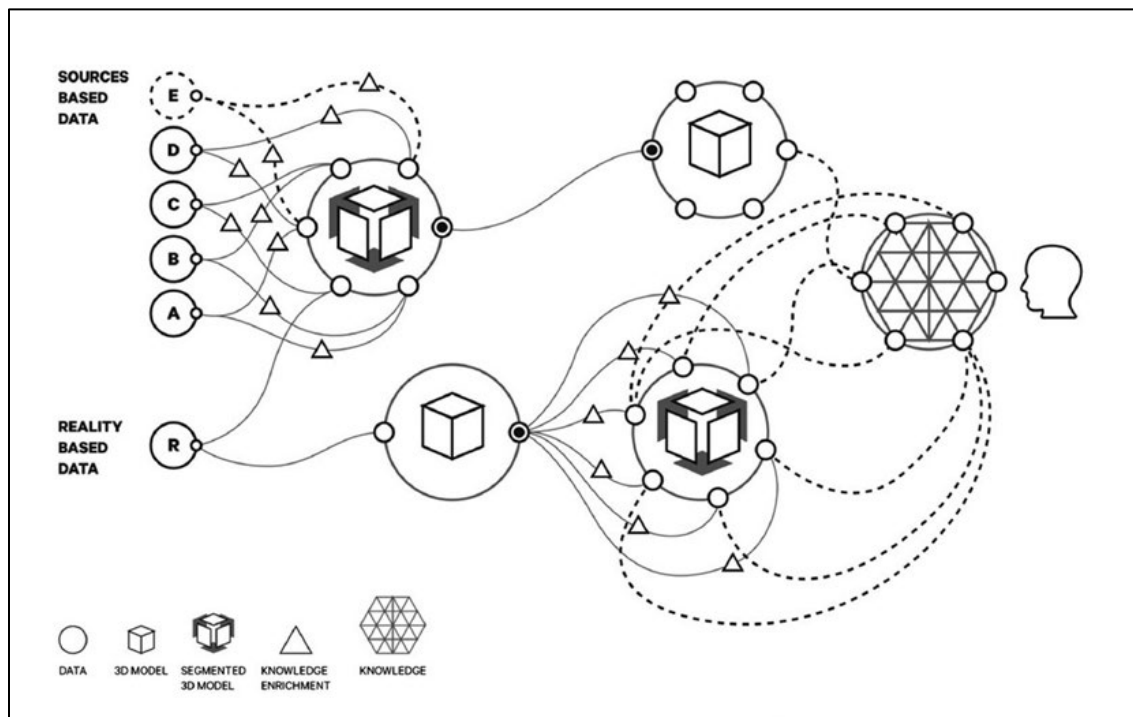

Figure 1: Apollonio's illustration of the reconstruction process workflow

[5] Fabrizio I. Apollonio, "The Production of 3D Digital Archives and the Methodologies for Digitally Supporting Research in Architectural and Urban Cultural Heritage," *Digital Research and Education in Architectural Heritage Communications in Computer and Information Science*, 2018, 139-58, doi:10.1007/978-3-319-76992-9_9.

[6] One might also argue for procedural/algorithmic models (rule-based generation of 3D models) and games that use 3D materials, but those two forms represent a minute fraction of 3D scholarship and currently can be considered sub-sets of sources-based models.

Both of these distinct types of scholarship have their own digital file formats, use requirements, intellectual property concerns, and preservation issues. Reality-based computer models, whether generated computationally from a laser scan or photographs, are typically single objects or a spatially compact piece of a building or site. These reality-based models are relatively quick to generate from scan or photo data, so are attractive to scholars because the results are immediate. The results are also well suited to pedagogical applications as teaching and learning objects. A perfect example of this is the University of Michigan's Museum of Paleontology's online repository of fossils and the UMORF viewer they developed to examine 3D fossil surrogates.[7] Academic discussions are ongoing about appropriate file formats, standards, and required metadata for interoperability and preservation purposes related to reality-based models. Similar conversations about sources-based models have begun, but are nowhere near as robust. While these two lines of inquiry are complementary, the standards, user interaction requirements, and long term preservation strategies for the two types of models are quite different. It is important that the 3D community recognize that what works for reality-based models is not likely to work for sources-based models and vice versa.

The differences between sources- and reality-based models dictate the requirements for their re-use and dissemination.

Given the differences in the two main types of models, it should come as no surprise that they have very different issues and requirements for re-use and dissemination, including the type of interface needed to deliver the material to its intended audience. Five key differences between the two types of 3D content stand out:

1. ***Workflow.*** The workflow to create sources-based models is very different from that used to generate reality-based models. Reality-based models are generated using data captured from an extant object or site. The basic process involves securing access to the object or site, assembling the proper equipment (e.g., laser scanner or camera), capturing the data, processing the data using the appropriate software (e.g., Agisoft's Metashape, formerly known as PhotoScan[8]), and cleaning and exporting the 3D object. Analysis of the model follows its completion, either as a stand-alone object or as part of a corpus. In contrast, sources-based models are often reconstructions of demolished or altered sites or buildings, with no extant remains available (e.g., ancient Rome, the World's Columbian Exposition of 1893). Creation of these models requires significant amounts of archival research, subject-expert knowledge of the environment in question and related contemporary structures, extensive interpretive decisions, and laborious computer modeling. Whereas a reality-based model may take 20 hours of labor to generate, a sources-based model may take 20,000 hours to create. As a result of this time differential, there is currently an emphasis on reality-based models to the detriment of sources-based work.

2. ***Interaction and interface requirements.*** As reproductions of stand-alone objects (e.g., statuary and artifacts) or spatially discrete building components (e.g., the doorway of a Gothic cathedral or entry hall of a cultural heritage site), interaction with reality-based models tends to be fairly limited with an emphasis on rotation (i.e., 'spin the artifact') and zooming. Given these limited requirements, it is relatively easy to develop viewers for reality-based objects. At the time of this writing, the burgeoning 3D community associated with the IIIF is developing a list of available 3D viewers for reality-based models. The most

[7] "Class Mammalia," University of Michigan Online Repository of Fossils, accessed December 1, 2018, https://umorf.ummp.lsa.umich.edu/wp/vertebrate-2/class-mammalia/.

[8] "Agisoft Metashape," Orthophoto & DEM Generation, accessed December 1, 2018, https://www.agisoft.com/.

robust of the options for scholars include Sketchfab (developed by a commercial, for-profit company),[9] the open-source viewer 3D HOP,[10] the aforementioned UMORF, and the IIIF Universal Viewer.[11] A team at the Smithsonian has also worked with AutoDesk to develop an object viewer which is arguably the most feature-rich of all, but it is not currently available for use with content beyond that posted by the museum team.[12] Discipline-specific viewers may also include special features to facilitate use of the 3D object in research. The University of Michigan's UMORF viewer, for example, includes the ability to measure the distance between two points on a fossil sample, and to view the object in anaglyph stereo. With more complex, sources-based models, where the intent is to facilitate prolonged interaction through the virtual environment, the navigation requirements are very different. In addition to simple rotation and zoom capabilities, the user must have complete control over their exploration of the virtual environment. This could mean pedestrian-level engagement or in flight simulation mode with full control of speed, direction, and duration. Robust environment viewers would also need basic lighting options, different render modes (solid, textured solid, wireframe, and point cloud), and settings for field of view and model units. (VSim 2.0 meets these requirements and more.[13])

3. *Annotations.* Both reality- and sources-based models require some form of annotation, and secondary users need to be able to access this information within their respective viewers in order to build a base understanding about the model and simulated object/environment. The character of the metadata, however, may be different between the two different types of models. For a reality-based model, basic metadata may be sufficient, and should include, at a minimum, information about the object represented and the circumstances of the data capture used in generating the 3D model.[14] The required annotation for a sources-based model is decidedly more complex. PI Snyder has previously argued that annotation within sources-based models must take into consideration five layers of information: "the source material used by the content creator to inform the reconstruction, introductory information to explicate the environment for users, paradata documenting the processes used during its creation, academic argumentation, and paratextual information created by peer reviewers,

---

[9] Sketchfab is currently placing a lot of emphasis on developing a marketplace for 3D objects, but it does include a section for free content available for use under Creative Commons Attribution-NonCommerical license. SketchFab is important because it provides a platform for reality-based models either generated or appropriate for use by academics; these models can be downloaded and used in VSim with reasonable degrees of success. (http://sketchfab.com)

[10] Most of the examples in the 3D Hop gallery are of single objects. The open-source viewer allows zooming, lighting adjustments, measurements, and annotations of the models. (http://vcg.isti.cnr.it/3dhop/)

[11] IIIF Universal Viewer includes ten sample 3D objects that can be rotated and examined in details. Each includes a brief description of the object and its source. (http://universalviewer.io/examples/)

[12] The options on the Smithsonian viewer for annotation ('tours' in their parlance) are of particular importance for the academic community. (https://3d.si.edu/)

[13] The inclusion of VSim's object navigation mode means that the interface could be used equally successfully with reality-based models, with a few caveats. As released, VSim 2.0 does not include the discipline-specific features needed for the analysis of cultural heritage objects (e.g., the ability to measure object elements or adjust the lighting source). Future work might explore ways that the VSim software and repository can address the needs of reality-based modeling communities.

[14] See CS3DP meeting notes for a matrix of metadata recommended for the use and preservation of reality-based models.

editors, or secondary users."[15] And within a sources-based model, these annotations must adapt to changes in scale, time, and user interaction.

4. ***Intellectual property and copyright concerns.*** Because of the difference in the generation/creation process, academics involved in different types of 3D work will have significantly different attitudes about sharing and distributing their models. The emotional and intellectual investment in reality-based models is significantly less than for sources-based models. Christine L. Borgman *et al.* (2007) have described this phenomena with research data, setting up an inversely proportional relationship between the effort required to collect the data and a scholar's willingness to share that data with others.[16] This concept of 'hard won' data translates well to attitudes about broad dissemination of reality- versus sources-based models. Where the distribution of reality-based models is typically encouraged as a community good (e.g., a discipline-specific and community-built archive of 3D scans of bones, molecules, arrow points), the creators of academically generated reconstruction models of historic sites or environments are typically more invested in their 'hard won' outputs, and therefore want more control over the use and dissemination of their work. Moreover, it is possible for the creators of sources-based models to invoke copyright on their work. In a 2015 SketchFab blog on the legal aspects of 3D scanning, the author refers to the ruling on *Bridgeman Art Library, Ltd. v. Corel Corporation* to assert that "perfect replicas of public domain artworks are not copyrightable, if the reproductions are slavish or lacking in originality."[17] As such, the intellectual property concerns are very different for those scholars generating reality-based models than for those investing a great deal of intellectual effort into building a sources-based reconstruction model of an historic site or imagined environment, and the interface requirements must accommodate these differences.

5. ***File formats.*** Viewers built for reality-based models typically only have to accommodate a single digital file that includes the geometry associated with the models. This geometry is usually in the form of a mesh overlaid with textures (i.e., digital images). Occasionally, reality-based models also include rendering information for the viewer to replicate the visual qualities of real-world materials (e.g., glass, shiny chrome, concrete). The geometry in these individual model files is typically very dense, and the file size itself is typically tied to the size of the texture map(s). In contrast, models that are constructed for interaction (e.g., sources-based models, computer games), typically comprise thousands of individual models that are arranged in a spatially controlled and hierarchical fashion. The UCLA model of the World's Columbian Exposition, for example, represents nearly a square mile in the physical world. The buildings, hardscapes, and plantings of that model are broken into seven distinct zones, each constructed with multiple and increasingly narrow spatial groups with buildings and details throughout, down to the streetlamps and individual plants. The scale of this model requires that the geometry be carefully controlled with levels of detail to optimize

---

[15] Lisa M. Snyder, "VSim: Scholarly Annotations in Real-Time 3D Environments," *DH-CASE II: Collaborative Annotations on Shared Environments: Metadata, Tools and Techniques in the Digital Humanities - DH-CASE 14*, September 16, 2014, doi:10.1145/2657480.2657483.

[16] Christine L. Borgman, Jillian C. Wallis, and Noel Enyedy, "Little Science Confronts the Data Deluge: Habitat Ecology, Embedded Sensor Networks, and Digital Libraries," *International Journal on Digital Libraries* 7, no. 1-2 (2007): 17-30, doi:10.1007/s00799-007-0022-9.

[17] SketchFab Team, "3D Scanning and the Law: Cultural Heritage," *3D Scanning and the Law: Cultural Heritage (blog)*, March 11, 2015, accessed December 1, 2018, https://blog.sketchfab.com/3d-scanning-and-the-law-cultural-heritage/. Referred to *Bridgeman Art Library, Ltd. v. Corel Corp., 25 F. Supp. 2d 421* (S.D.N.Y. 1998) (U.S. District Court for the Southern District of New York November 13, 1998) (Justia, Dist. file), https://law.justia.com/cases/federal/district-courts/FSupp2/25/421/2325910/

performance during interaction. It should be apparent that viewers built for compact reality-based models will have significantly different use requirements than those built for large-scale, sources-based models.

Publishing and peer review in 3D is still a work in progress.

Two key requirement for a mature form of knowledge production are the ability to peer review and publish the output as part of the ongoing academic discourse. The discussion below focuses on 3D work that is peer reviewed and published on its own merits rather than static images or fixed animation clips generated from 3D models that only accompany text-based publications. One can easily imagine a continuum of 3D publications, with static images illustrating a text-based argument on one side, and a fully interactive, stand-alone 3D publication on the other. The reality is that there are still limited opportunities for 3D publishing, a void that VSim 2.0 was designed to address.

In addition to online 3D warehouses and digital libraries like Europeana Collections, the position paper on 3D publication from the 2016 NEH-funded Advanced Challenges in Theory and Practice in 3D Modeling of Cultural Heritage Summer Institute identified only three venues for academic 3D publications – Elsevier's *Digital Applications in Archaeology and Cultural Heritage* (*DAACH*), a University of Michigan Press venture to develop digital publishing platforms for long-form scholarship (including 3D work), and the *Journal for the Society of Architectural Historians* (*JSAH*).[18] In the two years since that Summer Institute, opportunities for 3D publications have advanced, but only slightly. *DAACH* no longer supports interactive 3D work, instead stating that it is "compulsory to submit a video or animation file for the 3D archaeological models and Virtual Environments."[19] Authors are, however, encouraged to submit supplementary 3D models to *Studies in Digital Heritage*, a new journal launched by Bernard Frischer, one of the original editors of *DAACH*, and supported by the University of Indiana Press. According to the author guidelines, "the journal supports WebGL services such as Sketchfab and 3DHop as well as Unity WebGL players."[20] The University of Michigan Press successfully released *A Mid-Republican House from Gabii*, an online publication that includes a 3D model that uses a customized Unity interface.[21] And finally, *JSAH* successfully published "Digital Karnak: An Experiment in Publication and Peer Review of Interactive, Three-Dimensional Content," an article that described the creation of a publication prototype in VSim 1.2.1. and included links to the interactive model.[22]

A bright spot in the 3D publishing horizon is the NHPRC/Mellon grant noted above. Spearheaded by Angel David Nieves (SDSU) and Elaine A. Sullivan (UCSC), the initial planning grant for

---

[18] See archived webpage: https://web.archive.org/web/20161020213242/http://advancedchallenges.com/position-paper-publishing-3d-work/

[19] Elsevier, "Guide for Authors," accessed December 1, 2018, https://www.elsevier.com/journals/digital-applications-in-archaeology-and-cultural-heritage/22120548/guide-for-authors. Elsevier is still, however, promising an object viewer for "molecular models, crystallographic data, neuroimaging data, radiological data and universal 3D models." (https://www.elsevier.com/authors/author-services/data-visualization)

[20] Indiana University, "Author Guidelines," IU South Bend Undergraduate Research Journal, accessed December 1, 2018, https://scholarworks.iu.edu/journals/index.php/sdh/about/submissions#authorGuidelines.

[21] Rachel Optiz, Marcello Mogetta, and Nicola Terrenato, 2016, *A Mid-Republican House From Gabii*, Ann Arbor, MI: University of Michigan Press, 10.3998/mpub.9231782, https://www.press.umich.edu/9231782/mid_republican_house_from_gabii.

[22] Elaine A. Sullivan and Lisa M. Snyder, "Digital Karnak: An Experiment in Publication and Peer Review of Interactive, Three-Dimensional Content," *Journal of the Society of Architectural Historians* 76, no. 4 (December 27, 2017): 464-82 doi:10.1525/jsah.2017.76.4.464, http://jsah.ucpress.edu/content/76/4/464. The model is available for download from https://vsim.library.ucla.edu/xmlui/handle/20.500.11991/1012.

"Scholarship in 3D" is nearing completion at the time of this writing, with a second phase implementation proposal in development. If funded, the project would create the framework for a cooperative of presses committed to publishing 3D work. The current planning grant includes the University of Georgia Press, Stanford University Press, University of Michigan Press, and the Cotsen Institute of Archaeology Press.[23] After a series of discussions about viewers and interfaces, the project team decided to focus on a limited suite of technology options for the cooperative's publications, and is including VSim 2.0 as one of those options for the implementation grant proposal.

The desired functionality for academics working with 3D material seems to be finite.

One of the key questions explored by the VSim project was the functionality required to successfully enable the use of interactive computer models in both formal and informal educational settings, and the interface was designed to meet those requirements. A related question is the functionality required for the publication of 3D projects. As part of the NHPRC/Mellon funded planning grant project team, scholars with significantly different computer reconstruction projects worked together to develop a list of author requirements for 3D publications, and by extension a 3D viewer.[24] The four scholars (and their projects) were Susan Schreibman (Battle of Mount Street Bridge), Costas Papadopoulos (Neolithic House), Elaine A. Sullivan (3D Saqqara), and Angel David Nieves (Virtual Soweto). Happily, VSim 2.0 easily fulfills their list of requirements for publication:

1. ***Publication opportunities that place emphasis on the models/virtual worlds as text.***
   VSim 2.0 was specifically designed for prolonged engagement with large-scale, highly detailed virtual environments that are complex enough to support user-driven exploration and discovery.

2. ***The ability to annotate the virtual environments.***
   VSim 2.0 provides two different mechanisms to augment the virtual environment with information and academic arguments. Through the embedded resources function, content creators can annotate their models with spatially aware text and links to primary and secondary resources, and categorize their data as appropriate. Resources can provide users with a range of information, from discussions about the interpretive decisions made during the construction of the model to a history about the modeled environment. The narrative function allows content creators (and secondary scholars) to craft linear arguments that unfold during movement through the model.

3. ***The ability to showcase temporal aspects of the environments.***
   VSim 2.0 includes two mechanisms for displaying changes in the modeled environment. The first is a 'Time Slider' that controls time-based changes (e.g., a model that includes components that are visible from 1903-1915, others visible from 1905-1934, and still others visible only from 1925-1934). Time-based changes can be set through the scenegraph in models built with Presagis' Creator, or by importing discrete model elements and assigning them beginning and end years in the VSim 2.0 Model Outliner. The second temporal mechanism involves binary switches (e.g., Phase 1, Phase 2) that can be set only through the Creator scenegraph.

4. ***Flexibility to accommodate a range of publication options.***
   VSim 2.0 was designed as a generalizable interface that could be used for a variety of 3D

---

[23] Additional presses may be added for the implementation proposal.

[24] The list is a part of ongoing grant fulfillment documents and currently unpublished.

projects. In terms of publications, the scope of the environment and the focus of the annotations could easily accommodate different types of publications. An expansive environment coupled with extensive annotations could serve as a monograph equivalent; the same environment with an emphasis on the context and history of the simulated environment – along with paradata to explain interpretive decisions – could serve as a scholarly digital edition; a smaller-scale environment with limited annotations could be the equivalent of a peer-reviewed article.

5. ***Technology choices that are both intuitive and sustainable.***
Intuitive technology is subjective. To a gamer, VSim 2.0 is intuitive and easily mastered. To a novice who's never interacted with 3D models before, there is a learning curve. The software was designed to be as simple as possible, given its capabilities. Sustainability is easier to quantify, and VSim 2.0 was specifically designed as an offline interface so that it would be less affected by external dependencies (e.g., web browser upgrades, plug-in deprecation). Moreover, the VSim Repository and Archive was developed explicitly for the preservation and dissemination of 3D scholarship.

Given that VSim 2.0 addresses the common list of requirements developed by the four NHPRC/Mellon scholars, the software would seem a natural fit for their projects, yet they continue to look for other interface options. The key question is why? Possible explanations are discussed below.

We really have to consider the full spectrum of 3D work.

One of the main arguments for the development of VSim was the need for generalizable software that could be used by the academic 3D community, and while this argument is still valid, in reality, the 3D community needs a range of software interfaces that can address a range of project needs. Just as there are different interface needs for reality- and sources-based models, there are different interface and dissemination needs across the spectrum of sources-based models. At one extreme, use of a basic object viewer might suffice for presentation of the 3D material; somewhere in the middle, the interface must also accommodate annotations and basic first-person interaction; and at the other extreme, the focus is on prolonged interaction with an information-rich virtual environment with multiple modes of interaction. VSim 2.0 addresses this latter use case and project need.

Development of and access to a suite of common tools and interfaces that includes VSim would allow the academic discourse of the 3D community to mature, and that is the approach being promoted by the NHPRC/Mellon scholars. In addition to VSim, they are also exploring publication solutions that use ESRI's proprietary viewer, a downloadable Unity scene viewer, and a browser-friendly WebGL viewer and a Unity ingest workflow. Having such a suite of common interfaces available to scholars working with 3D material would reduce the amount of effort and money spent developing bespoke software solutions for individual projects. Moreover, it would allow scholars to focus on research questions and knowledge production instead of the mechanics of interfaces and software development. Thus, the field can finally shift to discussion of peer review, publication, and preservation rather than continuing the early conversations about 3D scholarship that focused on questions of creation (e.g., expressing transparency and ambiguity within a 3D model). Indeed, these more mature conversations are happening, but remain hobbled by the constant quest for new technologies, software applications, and delivery platforms. For 3D scholarship to gain acceptance in the mainstream disciplines, practitioners need to work together on collective requirements, and embrace a suite of tools that will work for the majority. This was the challenge for the VSim team – to make an interface that fulfills the requirements of academic 3D projects, is flexible enough to provide

scholars with options for interacting with and disseminating their projects, and is customizable enough to respond to different project needs. Where VSim addresses one end of the sources-based 3D spectrum, work remains to address the balance.

Why isn't VSim online? And does that matter?

The white paper for the VSim prototype included concerns that users would eschew the software because it didn't accommodate avatars and social interaction. While that fear has largely abated following the relative demise of online virtual worlds and the avatar obsession, it was replaced by fears that VSim 2.0 will be shunned because the model content has to be downloaded and then accessed offline rather than allowing in-browser interaction. Considering the current ubiquity of the Internet in our daily lives, there is a pervasive expectation that all materials be fully online and immediately available for use. True, the sheer volume of data available online is both staggering and growing, but 3D material arguably represents only the tiniest fraction of a percentage of that online activity.[25] Broad acceptance of WebGL as an online 3D standard may change this, but the types of large-scale environments accommodated by VSim will still be challenging to deliver online. Technologically, online models are still limited by file and texture sizes, there are still problems with latency during interaction (a problem solved by the game manufacturers, but not shared with academics), and there are still challenges integrating 3D material with text-based web content. Similarly, there would be considerable functional challenges to porting VSim 2.0 to the web, including the need to develop mechanisms to integrate the 3D material with publication and peer review processes, and accommodate the constraints imposed on pedagogical use at schools not necessarily equipped with high-speed internet access or the permissions to interact with online content. Addressing those technical challenges is the work of computer scientists, and one day, fully navigable online worlds will be commonplace. Until then, downloading content and interacting with it offline is a reasonable solution.

CONSIDERATION OF THE EDUCATIONAL APPLICATIONS

Will in-service educators use it?

The VSim project provides a range of opportunities for in-service educators to use 3D materials in their classrooms. It accommodates both teacher-centered presentations and student-centered assignments (e.g., free-form exploration, narrative construction); the VSim 2.0 interface can be used with existing content from the VSim Repository and Archive, 3D materials from other sources (e.g., 3D Warehouse or Turbosquid), or with student-generated content (e.g., a class works collectively to make and annotate a historic environment, a model of their school). The white paper that followed the completion of the VSim prototype asked and answered similar three questions about use by in-service educators: "Is the software simple enough for educators to embrace? *Probably, given the right training materials and available content.* Will academics continue to build 3D content? *Yes, given that the task maps to their current research questions.* Will they be willing to share their models for educational use? *Probably, given the right combination of incentives and control over their intellectual property.*"

Use by in-service K-12 educators will hinge on a number of things, the most critical being the individual teachers' ability (and willingness) to incorporate the 3D material into their curriculum.

---

[25] Discussions of online data address text-based activities, photos, videos, and sound files. See http://www.internetlivestats.com/ and https://www.forbes.com/sites/bernardmarr/2018/05/21/how-much-data-do-we-create-every-day-the-mind-blowing-stats-everyone-should-read/#25891af60ba9

As gatekeepers, their choices dictate whether or not the technology has a place in the classroom, how the material is to be used, and the amount of time to be dedicated to interaction with the environments and the content. Key to those decisions is how well the 3D material links to the learning objectives for the class. If the learning objective is to build subject-based knowledge, the 3D environment has to closely align to existing lesson plans, or be easily integrated into the learning standards that govern the curriculum. UCLA's model of the World's Columbian Exposition, for example, is of great interest to educators in Illinois where the state learning standards include coverage of the fair.[26] This places emphasis on canonical works (e.g., the Roman Forum, major cathedrals), and suggests the need for pre-made narratives that can help educators integrate the content into their classrooms. Learning objectives for the 3D exploration, however, need not be tied exclusively to acquisition of subject-based knowledge. The REVIST project (Research Engagement through Virtual Immersive Tools for Learning), run by researchers at the Glasgow School of Art and the University of Hull, used the VSim prototype to study the pedagogical use of an interactive 3D model of the British Empire Exhibition.[27] Beyond building subject-based knowledge across their study participants, the REVIST team connected use of the 3D environment to development of "cross-curricular skills such as collaboration, leadership, creativity, and emotional intelligence."[28] The REVISIT study included classes at three schools in the United Kingdom, one primary and two secondary. At Young's Primary, the instructors took a theme-based approach to the material, and successfully used the modeled exhibition as hook for other material, such as math, geography, and critical thinking. The study recounted how one of the instructors "described the Empire Exhibition theme as the most successful he'd ever seen and went on to describe not only the way in which the 3D scene had been used to deliver the curriculum but also its longevity as a teaching tool."[29]

For post-secondary instructors, learning objectives for the 3D material seem to vary according to the modeled environment. Anecdotal evidence suggests that the post-secondary instructors downloading the Digital Karnak model are focused on the acquisition of subject-based knowledge and are teaching courses that directly align with the model (e.g., Egyptian history, art history, architectural history, archaeology). Academic requests for the World's Columbian Exposition model, on the other hand, have come from both instructors in programs with an obvious interest in the fair (e.g., architecture departments, history programs), and disciplines more interested in the methodology of the project (e.g., digital humanities, media studies, digital ethics). There is also quite a bit of non-academic interest in the Columbian Exposition model, likely a result of general interest in the exposition and the publicity surrounding public presentations of the project.

---

[26] Illinois State Board of Education, "Born, Built, Grown. Illinois Learning Resources from the People's House," accessed December 1, 2018, https://www.isbe.net/bornbuiltgrown. See pages 13-15 on the accompanying PDF.

Illinois State Board of Education, "The Illinois Chronicles Educator's Guide," accessed December 1, 2018, https://www.isbe.net/Documents/Illinois_Educators_Guide.pdf. See pages 10-11 on the accompanying PDF.

[27] The School of Simulation and Visualization at the Glasgow School of Art, "REVISIT Outputs", accessed December 1, 2018, http://blog.gsofasimvis.com/index.php/research/heritage/revisit/outputs/.

[28] Daisy Abbott et al., "Development of Cross-Curricular Key Skills Using a 3D Immersive Learning Environment in Schools," *Communications in Computer and Information Science Immersive Learning Research Network* 725, 2017, 60-74, doi:10.1007/978-3-319-60633-0_6, http://radar.gsa.ac.uk/5323/1/REVISIT%20paper%20for%20iLRN-v2.pdf. A. Gouseti et al., "The Potential of Virtual 3D Models in Primary and Secondary" (presentation), December 16, 2016, accessed December 1, 2018, https://prezi.com/hjzv6w-qflsw/the-potential-of-virtual-3d-models-in-primary-and-secondary/?utm_campaign=share&utm_medium=copy.

[29] Ibid.

Wait, I have to learn to fly?

The most significant challenge to the adoption of the software in the classroom is the effort required by the instructors to learn how to navigate and use the software. Following the development of the prototype, the VSim development team realized that this was going to be the case, and expressed concerns about the navigation learning curve in the concluding white paper:

> "One of the greatest challenges encountered during the VSim development was taking complex interactions within a virtual world and simplifying them for use by in-service educators. The project goal was not to produce software for tech savvy graduate students and researchers – although VSim can address their requirements – but rather to produce software that would be non-threatening and encourage the use of 3D content in the classroom."

For general classroom use, depending on a specific user's technical prowess, one might expect them to overcome the learning curve somewhere between 30 minutes to an hour. That figure would be significantly less if the user in question has gaming experience, but significantly higher if they are a technological novice, suggesting that students and young adults will have no problems mastering the software while adults and senior scholars without experience with 3D environments may find it daunting. The REVISIT team acknowledged this challenge, but turned it into a positive constructivist experience:

> "[A] major challenge for using 3D environments in the classroom is the requirement for teachers to become expert users. Whilst this can certainly create problems, REVISIT data demonstrated that occasional frustrations from students regarding a teacher's lack of technical knowledge were far outweighed by opportunities for developing leadership skills in students."[30]

The steepest learning curve is for those interested in using VSim 2.0 to successfully combine 3D content with contextual material to build an information-rich learning environment for distribution. To construct their binary VSim file, these content creators will need to understand the mechanics of importing 3D material, the VSim 2.0 settings for lighting and camera control, and the settings to protect their intellectual property (e.g., the branding overlay, the model information menu, export settings). Annotating the model with the information necessary for a secondary user requires another layer of significant effort. Beyond mastering the mechanics of creating narratives and embedded resources, the content creator will need to assemble the appropriate metadata, contextual information, historical information, paradata, and auxiliary files for distribution and spatially embed them into 3D environment. Mastery at this level is likely beyond a general user, but well within reach of an academic already working with 3D material and modeling programs.

Next steps (Phase 3 and beyond)

The ultimate goal of the VSim project is to build a community of content creators willing to share their content for pedagogical use, and a community of users eager to use 3D materials in their classrooms and share their experiences with other in-service educators. Engaging these communities will require coordinated promotional campaigns that build awareness of the VSim 2.0 software and the available content in the VSim Repository and Archive. The next steps for the project team are to develop and post online complete VSim 2.0 users guides and project videos (at the time of this writing only an abridged users guide is available), build VSim 2.0 files

---

[30] Abbott, section 4.4.

for as much content as possible and post those files in the repository, develop and distribute announcements for VSim 2.0. and the repository, solicit new content from academics working with 3D materials, and plan for and develop any desired post-grant software changes (e.g., paths, exposed LOD controls, sound integration). The team also would like to work with in-service educators to continue testing pedagogical applications for 3D material, and publishing studies to supplement the growing body of literature on classroom uses for 3D interactive environments.

Conclusions

The conclusion of the white paper for the prototype grant asked and answered two simple questions: "Was the prototype development process worth the effort? *Definitely*." And "What will it take to realize the [VSim] project's vision? *Commitment. Energy. Time. Talent. Coordination. Marketing. Buy-in. Funding*." Five-and-a-half years later, those same questions are valid, and the responses are pretty much the same. Yes, the process was worth the effort. There is a demand for 3D material in the classroom, and a growing community of scholars interested in expanding the boundaries of knowledge production. What will it take to realize the VSim project's vision? Here the response is more developed. Definitely commitment from a team of academics and educators interested in 3D material. Considerable energy, time, and buy-in from educators across the country to test and use VSim 2.0 to facilitate innovative classroom experiences. Academic interest in sources-based models, the talent to build them, and a willingness to share the results with others. Coordination and marketing to locate new materials and build the necessary communities of users. And, of course, funding. But most of all, commitment.

If you are interested in working with VSim or making your own 3D content available for educational use, please contact Lisa M. Snyder (*lms@ucla.edu*) at UCLA's Office of Information Technology/Institute for Digital Research and Education.

The VSim Project Team

Principal Investigators
Lisa M. Snyder and Scott Friedman

Prototype Programmers (VSim 1.0 through 1.2.1)
Eduardo Poyart, Jingyi (Franklin) Fang, and XinLi Cai

Prototype Usability Consultants
Elaine A. Sullivan and Joy Guey

Production Version Programmers (VSim 2.0)
David Stephan (Lead) and Sam Amin

Content Developers
Francesca Albrezzi (Lead), Aaron J. Taber, and Echo Theohar

VSim Repository and Archive Development
Lisa McAulay, Kristian J. Allen, Peter Broadwell, Hardy Pottinger, and Anthony Vuong

Acknowledgements

The VSim logo was derived from an image entitled 'food pyramid' by Simon Sim from the Noun Project.

VSim is distributed under a BSD-3-Clause license. Copyright (c) 2018, The Regents of the University of California. All rights reserved. The software includes the following components, licensed as noted:

- OpenSceneGraph - OSGPL 0.0 (wxWindows, LGPL)
- Qt - LGPL 3
- OSGWidget - Bastian Rieck, MIT License
- DroidSans.ttf - Apache License 2.0
- Material desgin icons - Google, Apache License 2.0
- QDarkStyleSheet - Colin Duquesnoy, MIT License, Creative Commons Attribution International 4.0
- Crypto++ - Boost Software License 1.0